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# HYPERCANES AS A CAUSE OF THE 40-DAY GLOBAL FLOOD RAINFALL

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## KEYWORDS
Deluge, precipitation, catastrophism, canopy alternatives, plate tectonics alternatives, cyclones, storms, stratosphere, suboceanic volcanism, fountains of the great deep, antediluvian climate, troposphere-stratosphere exchange processes, stratospheric water, forty days and forty nights, ice clouds

## ABSTRACT
Hypercanes can either supplement, or replace, other non-canopy mechanisms (extraterrestrial causes, volcanoes, jets of subterranean water, etc.) as the primary source of the worldwide rain at the start of the Flood. Hypercanes form from large (50 km diameter), superheated (50 C) thermal anomalies on the ocean surface, which have in turn been generated either by volcanism or hydrothermal action on the ocean floor. In the model hypercane, water material from the ocean is injected all the way into the stratosphere, which places the resulting ice clouds at sufficient altitude to remain aloft until they can be advected over continents. The ice crystals undergo repeated cycles of gravitational settling, sublimation, and re-crystallization. This, along with conventional stratospheric-tropospheric exchange mechanisms, eventually makes copious amounts of water material available to synoptic weather systems in the troposphere, giving rise to considerable rainfall. Additional rainfall precipitates directly from any remaining ice clouds.

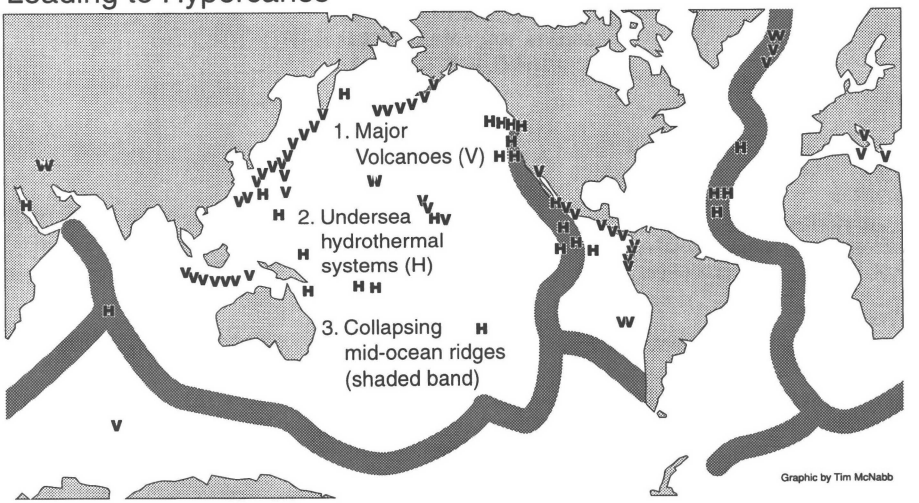
## INTRODUCTION
A hypercane [20] is a recently-modeled intense storm which is believed to arise under certain catastrophic conditions. Owing to its unimaginably powerful convective updraft, is of interest to Scientific Creationism. The purpose of this work is to model hypercane-injected stratospheric water substance and its subsequent dispersal and eventual precipitation all over the earth in the first weeks of the Flood. The massive stratospheric ice clouds are first modeled as passive tracers, and then are considered in the light of convective activity as they undergo solar heating. For purposes of clarity, the term "water substance" encompasses liquid, vapor, and ice. Also, the general term "ice clouds" is used (instead of the more-specific cirrus, cirriform, or stratiform) to describe relatively flat ice-crystal dominated clouds.

Figure 1 illustrates the main loci of heat responsible for the possible generation of hypercanes during the Flood. These include existing seafloor hydrothermal systems [51], undersea volcanics [1, 21, 51], other volcanics [1, 21] (not necessarily shown) which erupted subaqueously under a thick cover of Floodwater, and possible secondary sources of heat released by tectonic activity along the mid-ocean ridges [74] (stippled). More on this later.

## THE NATURE OF HYPERCANES
These are essentially "hyper-hurricanes". As with conventional hurricanes, they derive most of their power from the gradient of sea-surface temperature [16], and can only exist over water. They differ in that they are self-triggering once the proper conditions are met [20], whereas conventional hurricanes need to be initiated by an exogenous disturbance. Also, whereas conventional hurricanes derive their power from water warmed by tropical climatic conditions (25-30C), hypercanes form and derive their power from much hotter (typically 40-50 C) but more localized (typically 50 km diameter) ocean-surface temperature anomalies. The pressure in the eye of a hypercane is much less than that of a conventional hurricane [20], and the updraft of the former is considerably more powerful than that of the latter. For this reason, according to models [20], hypercanes are capable of lofting water substance well into the stratosphere (30 km)[20], whereas conventional hurricanes seldom penetrate the tropopause. Owing to the fact that hypercanes can only form

and sustain themselves over areas of unusually hot ocean surface temperatures, they are relatively stationary compared with conventional hurricanes. If surface winds are strong enough to displace the hypercane off the patch of superheated ocean surface,

Fig. 1. Location of Heated Water Potentially Leading to Hypercanes




it will soon die down [20], but then a new hypercane will perhaps form over the thermal anomaly [20]. In addition, the thermal anomaly must form rapidly enough so that a hypercane can form before the anomaly comes into radiative-convective equilibrium with the atmosphere [31].

The power of any kind of hurricane derives from the isothermal expansion of the low-level moist air as it moves horizontally over the warm surface of the ocean [18], and towards the lower pressure of the eye. In the eye of the conventional hurricane, there exists a balance between the inward-rushing winds in the eye wall, and the acceleration imposed by the Coriolis force. Other details of hurricanes, and their more powerful potential versions, are discussed by Vardiman [70]. In a hypercane, the power of the inrushing winds is of sufficient intensity to force the eye to be much smaller than in a conventional hurricane.

We do not know the limits of size or power of hypercanes. However, since their power must be limited by internal dissipation [17] at some unknown point, and this process is not well understood even for conventional hurricanes [19], it would be unwise to try to scale a model hypercane [20] to greater sizes or intensities. For this reason, I conservatively assume, for purposes of this study, that the hypercanes which are proposed to have existed during the Flood were no larger than the model hypercane [20]. Of course, possible variations in the height and magnitude of stratospheric-water injections can be briefly considered. Since height of atmospheric injection scales according to the 4th power of increase in potential temperature [20], it would take a 2.37-fold increase of it to raise the altitude of hypercane injection from 30 to 40 km [i. e., (40/30)E4=2.37]. As for the amount of material lofted, in whatever kind of hurricane, the scaling relationship is believed to be a linear function of the rate of upward-moving air [8]. However, the wide overall uncertainties in just the model hypercane makes attempts to scale relevant phenomena to larger hypothetical hypercanes of doubtful value, even as a sensitivity analysis.

For purposes of illustration, the model hypercane [20] is assumed to inject about 10E4 tons per second of water substance into the stratosphere. At this rate, it would have required several thousand hypercanes, operating for 40 days and nights, to have injected sufficient ocean water substance into the stratosphere to have eventually resulted in a 1-meter thick global rainfall during this period of time. The fact that each of these super storms cover much less area than one conventional hurricane implies that several thousand simultaneously-occurring hypercanes would only take up a small percent of earth's surface.

## RELATION TO PREVIOUS MODELS OF THE ANTEDILUVIAN ATMOSPHERE

In this work, canopy models are eschewed in favor of an atmosphere very similar to the one today--with conventional atmospheric circulation processes and meteorology. And, owing to the fact that the amount of potential rain produced is small (1 meter, or somewhat more), it follows that most of the water which covered the continents during the Flood must have come from a combination of uplifted ocean bottoms, and downwarped continental surfaces. Of course, this limitation is shared with canopy theories which, owing to indirect constraints imposed by surface-heating effects, cannot produce more than a few meters of precipitable water [57, 71], and that under the most favorable assumptions. Furthermore, and contrary to oft-repeated bogus anti-Creationist claims, the Bible does not teach that rainfall was the main source of water which covered the continents during the Flood [56]. The "fountains of the deep" refer not to springs but, analogously to the fountain of a fountain pen, to the ***reservoir*** of water stored by the ocean basins themselves. Their "breaking" thus means the spilling of the oceans unto land [56].

Why no canopy? Apart from the problems inherent in canopy models, conventional canopies themselves are all but incompatible with hypercanes. This owes to the fact that a warm stratosphere, which is a perennial problem for canopy models [57, 71] because of excessive earth-surface radiative heating, would also imply a prohibitively small difference in temperature between the superheated water surface and stratosphere. So hypercanes could not form [20]. The stratosphere must also be very cold (as it is at present) for another reason: Ice crystals must form, and be of sufficiently small size, in order that the water substance injected by hypercanes remain aloft for nontrivial lengths of time.

Let us consider a water-filled stratosphere under present conditions [68]. This will approximate the maximum impact of collective hypercane injections, and will allow us to contrast this with the water-filled stratosphere that would exist under canopy models [57, 71]. By way of introduction, the present-day stratosphere holds approximately 250 times ***less*** water vapor than it could if the pressure-temperature conditions therein were the limiting factor. The cause of this stratospheric aridity has been a mystery for decades. Current evidences indicate that the present stratosphere is constantly being dehydrated by the cold-trap effects of the Antarctic stratosphere [65], the adiabatically-cooled air above tropopause-piercing thunderstorms [11], and, especially, the kinetic effects of gravity waves caused by distant storms [15]. If there had been no ice caps before the Flood, as well as fewer and less severe storms than occur at present, the processes which dehydrate the stratosphere today would have been much less efficient than they are today, thus allowing a somehwat wetter stratosphere than occurs at present. This, in a sense, would be a "canopy".

Since the amount of water a given layer of atmosphere can hold is far more limited by temperature than by pressure [45, 47], a cold modern stratosphere (215 K) can only hold a water column of 25 cm per cm2 of earth's surface [68], in contrast to the 1-4 meters per cm2 of a stratosphere which is assumed in canopy models to have been created warm with a vapor canopy in place [57, 71]. Of course, as noted earlier, the latter figure is not constrained by the water-vapor holding capacity of the warmed stratosphere, but by the need to limit IR radiative heating of the earth's surface to tolerable levels. In summary, the traditionally canopied stratosphere is modeled to be warm and theoretically stable. A water substance-filled stratosphere, under conditions resembling the present-day stratosphere, would be cold and unstable. The latter would thus be subject to gravitationally and convectively induced rainout [68] of its water substance. Yet it is precisely this very instability which would cause the injected stratospheric water substance to precipitate in a short period of time.

What about the direct atmospheric effects of volcanic action during the Flood? This work either complements or replaces the idea that the extensive volcanic action during the Flood had materially contributed to the 40-day rainfall. Although much water vapor is present in magma and/or entrained from the surrounding air [23], it is now generally (but not universally [23]) held that most of the water substance in volcanic plumes is scavenged by the particulate matter in the plume [48], and thus very little persists in the stratosphere beyond perhaps a day. Furthermore, even when assuming that a generous 29% of the lofted volcanogenic water substance remains in the stratosphere, a Mt. St. Helens-sized volcano is much inferior to a single hypercane in terms of the quantities of water substance lofted into the stratosphere. The former is projected to inject 96 million tons of water substance into the stratosphere in a 24-hour period [23], compared with, perhaps, 0.7 of a million ton by a single severe thunderstorm [49]. Although one can, of course, envision larger thunderstorms and notably larger volcanic eruptions, this does not change the fact that both quoted amounts are dwarfed by the 1000 million tons lofted by a single model hypercane [20].

Possibly the only time that volcanoes inject large and lasting amounts of water substance into the stratosphere occurs when calderas entrain much seawater. For instance, approximately 200-300 million tons of long-lasting stratospheric ice crystals were injected by the 1994 Rabaul eruption [55]. While considering volcanoes, it should also be stressed that aerosol concentrations from volcanoes, and injected into the stratosphere, are self-limiting [48]. Therefore, the fact that a considerable number of volcanoes erupting during the Flood need not imply particularly severe postFlood climatic effects.

**RELATION TO PREVIOUS MODELS OF FLOOD GEOLOGY**

Assuming that the Bible does actually teach a universally-warm preFlood earth (and not just a warm Garden of Eden), and also an earth with no subfreezing temperatures anywhere, there then becomes a need for non-canopy models to account for such a global climate. Indeed, some conventional models [62] suggest a fullfillment of these requirements by an earth which has neither polar icecaps nor high mountain ranges [41], and one which has a 2-10 fold elevation of atmospheric CO2 content relative to that found today. Other models [62] indicate that, even under such conditions, it would be still difficult to avoid at least transient subfreezing episodes over continental masses at high latitudes in winter. This stems from the low thermal inertia of large land areas, which permits their rapid radiative cooling in the absence of sufficient incoming solar energy, and the magnitude of which cannot be offset by warmth advected to continental interiors even by unusually warm oceans. However, these models all assume uniformitarian paleogeographic deployments of sea and land. If, on the other hand, the antediluvian land masses had included a considerable number of properly-spaced epicontinental seas, the thermal inertia of continental interiors might have been sufficiently increased in order to allow for a constantly frost-free planet. This should be investigated.

This work assumes that continents have always been at their current locations throughout Earth's history, for a number of reasons. To begin with, this author is not convinced that surficial geology, when examined from a Creationist-Diluvialist perspective, either requires or even favors mobile continents. Second, any problem of excessive heating (and, possibly, excessive earthquakes) caused by the generation of large amounts of oceanic crust in a short period of time is avoided if it is assumed that ocean basins (and, of course, continents) have been permanent features of the Earth since its creation. Nor do hypercanes alleviate the problem of excessive heat caused by moving continents and new oceanic crust. In fact, based on an ocean-floor volcanic example [20], a single model hypercane can reduce the temperature of a 50C, 100 meter-deep temperature anomaly only by a mere 1C per day [20]. Clearly, then, hypercanes would be incapable of cooling a large area of hot oceanic crust (let alone a new Atlantic Ocean formed during or after the Flood), even if it were completely covered by long-lasting hypercanes. We thus have a rationale for accepting the existence of only localized volcanothermal effects during the Flood, which is consistent only with permanent ocean basins and continents. Finally, it is doubtful if hypercanes would form at all if the ocean were subject to the major disturbances which would certainly ensue if in fact continents were drifting apart in the early stages of the Flood. Owing to the fact that hypercanes are limited in duration to the time that surface temperatures remain high [20], only a small amount of immediate vertical mixing of ocean layers is compatible with hypercane genesis and existence. In a Flood setting, hypercanes had to form and complete their role before other effects of the Flood raised deeper, colder water to the surface, thus extinguished them. With stationary continents, we therefore have a basis for understanding how the ocean surface could have been stable enough for hypercanes to form and then last for a significant amount of time.

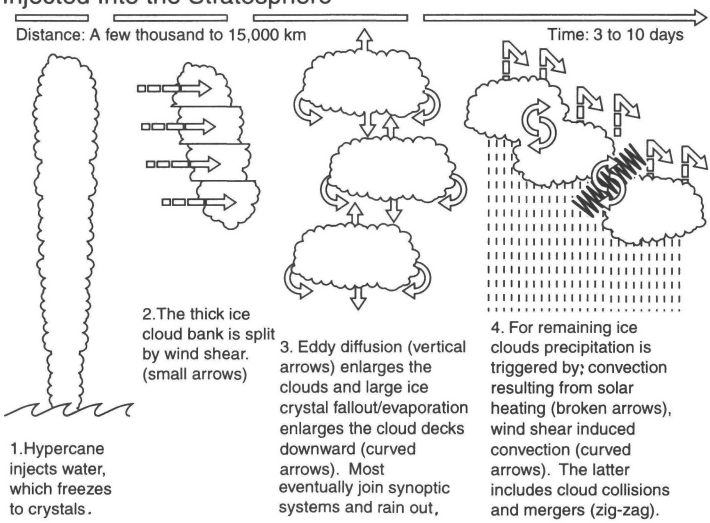
Whenever a large temperature anomaly would develop on the ocean surface, the Coriolis force would act to confine it geographically [20], except of course at the Equator. This would greatly inhibit any tendency for the anomaly to expand in radius and thereby become diluted and cooled by surrounding water. Such a process would not only enable the temperature anomaly to maintain its thermal integrity long enough for a hypercane to form over it, but would tend to serve as a "fence" which strongly divides the ocean into areas of high surface temperatures and contrasting nearby areas of near-normal temperature. Collectively, this confinement of thermal anomalies on the ocean to localized circular areas would have prevented significant areas of the ocean from becoming excessively hot to support life outside the Ark [73].

Brown [9], in his hydroplate model, and Zeman and Zeman [74], in their underwater-conduit model for midocean ridges, have proposed that vast amounts of subterranean waters were in effect squirted into the stratosphere by means of ascending fountain-like columns of water many kilometers tall. Now, owing to the fact that hypercanes provide a hitherto-unknown potential mechanism for transferring large quantitites

of ocean-water material directly into the stratosphere, they thus eliminate the need for any kind of direct injection of surficial water into the stratosphere.

Nevertheless, the present author generally favors the latter model [74], with the understanding that hypercanes potentially resulted as a secondary effect of the heat released by the movement and/or collapse of the mid-ocean ridge conduits of water (hashed area, Figure 1). Under such conditions, ocean-surface thermal anomalies must have resulted from underwater tectonic, volcanic, and hydrothermal actions. As a consequence, hypercanes would have been formed all over the world, but would tend to occur at the Pacific "ring of fire", and at the worldwide oceanic ridge system (Fig. 1). One consequence of this geographic deployment of hypercanes would be the fact that large stretches of the open ocean would be far from hypercanes, and thus there surfaces would have been relatively calm. This, of course, would have facilitated the survival of Noah's Ark [73].

Fig. 2 Temporal Evolution of Ice Clouds Injected Into the Stratosphere




Graphic by Tim McNabb

## STRATOSPHERIC TRANSPORT PROCESSES

This section discusses the advection of ice clouds unto the continents (Fig. 2). As an introduction, we should note that these clouds would resemble those which form as an adjunct to massive convective storms [32], albeit on a drastically larger scale, and at much higher altitudes.

Any hypercane-generated water substance must have been inititially transported by the ambient stratospheric circulation. Based upon analogies with the transport of recent volcanic plumes in the stratosphere [6,12,53], ice clouds and their water-vapor equivalents must have encircled the earth, at or near the latitude of injection, in about 15-30 days. However, since most hypercanes are distributed primarily in belts perpendicular to this flow (Fig. 1), the plumes that they created would have needed only to travel one-third of the way around the world, or less, before interacting convectively with other plumes (Fig. 2, stages III and IV; see below). As for meridional transport, plumes could expand at least 15 degrees in latitude within a week [6], not counting more dilute stringers [34]. Other estimates [7, 40] of such movements, based on horizontal eddy diffusivity in the stratosphere, predict an expansion of a 30-50 km wide cloud to a few thousand kms width in about a week.

Let us now consider the vertical eddy-induced movement of cloud constituents in the stratosphere. This movement occurs at rates orders of magnitude smaller than the aforementioned horizontal transport. The main factor which initially governs the survival, and thicknesses, of the ice clouds is the extent and rapidity at which the hypercane-generated plume is split into cloud decks by wind shear. Subsequently, the decks

will swell in thickness as a result of the eddy movements. For instance, if the wind shear slices the plume into cloud decks having thicknesses of 1 km, 100 m, or 10 meters, the respective thicknesses (in terms of vertical standard deviation) of these decks, after one week, will be about 10 kms, several kms, or a few kms. Of course, the outer fringes of this thicker cloud will be highly diluted [34], and the constituents of the cloud will achieve a vertical Gaussian concentration [7].

Meanwhile, the wind shear will continue interacting with the cloud decks throughout the duration of their transport, slicing them into progressively thinner decks. Provided that they do not dissipate first, the decks will eventually override each other, in whole or in part (Fig. 2, stage IV). This will cause convective overturn [63], followed by precipitation (see below). Wind shear will also move injected material in different directions from a given hypercane. As an example, consider the stratospheric plume of the Mt. St. Helens eruption. Winds at the 100 mb level rapidly moved the plume in a SSE direction, while the decks of the plume at the 70 mb and 50 mb levels were moved in a North and NW direction, respectively [12]. In fact, based on analogy with statistics applicable to the circulation of the modern stratosphere [51], it can be predicted that a plume injected into the layer found between 100 mb and 30 mb levels will commonly be split by winds moving in opposite directions.

Another major source of atmospheric tranport is Ertel potential vorticity. However, this does not become important until altitudes of about 22 km are reached, and then only at high latitudes [4]. Since only a small fraction of the hypercane-injected water substance could be significantly affected by this movement, I do not consider it further. The sublimation of ice crystals at the peripheries of stratospheric clouds can itself induce vorticity at an appreciable scale [13], increasing the rate of poleward spread of the remaining ice clouds. Owing to the complexity of this phenomenon, and its dependence on many factors (notably the degree of wind shear, which itself is highly variable in time and location), no attempt is made here to quantify it.

Depending upon the indirect effects of wind shear (Fig. 2, stage II), among other things, most of the ice clouds must have dissipated within hours or days of being generated by the hypercanes. Hence, the water substance must have been transported by the stratospheric circulation in the form of water-vapor anomalies. As these moved ever further from the hypercanes, they must have decreased in altitude as a balance to the upward-moving plumes injected by the hypercanes. Eventually, the water substance rained out as part of the normal lower-atmospheric synoptic meteorological processes.

Finally, let us consider subsidence at mid-latitudes. This stratospheric air-parcel movement would rapidly advect moisture directly into the troposphere, and also make the erstwhile-stratospheric water substance available to normal rain-producing tropospheric processes. In several places on earth [notably India (80E), northern Africa (10 E), Saudi Arabia and eastern Africa (30-40 E)], stratospheric-circulation models [45] indicate that subsidence will bring stratospheric materials down some 10 km in altitude within only a few days. It is interesting to note that this occurs over the Middle East, with possible meteorological significance for the first few days of the Flood. This, of course, supposes that the Ark began its voyage in that region.

## REMOVAL OF STRATOSPHERIC WATER SUBSTANCE

Let us, as a sensitivity analysis, suppose that ***all*** of the ice clouds dissipate and their ice crystal consituents sublimate very soon after being generated by the hypercane, and hence the microphysics and interactive transport of ice clouds become of no concern to this model. In such a situation, all of the water substance would manifest itself as water vapor (though supercooled droplets are briefly discussed below). The resulting humidification of the lower to middle stratosphere would continue until it is saturated by the ambient water vapor. We thus need a renewed appreciation of the fact that the current stratosphere is capable of holding much more water substance than it does at present. Typical mixing ratios in the lower and middle stratosphere today are in the few ppmv range, whereas saturation mixing ratios are on the order of 50 ppmv or more [45, 47]. Thus, any water vapor which undersaturates the stratosphere will tend to remain there until the stratospheric air containing it is brought down into the troposphere.

In the present atmosphere, most of this tropospheric/stratospheric exchange takes place at mid-latitudes, which is also the location of most of the continental masses. There are a variety of known mechanisms responsible for this transfer. However, for the time frame of interest to us (days to few weeks), probably the most important of these is the turbulent mixing of air near the tropopause [60]. A long, curved "tongue" of stratospheric air is irreversibly mixed into the troposphere in conjunction with the passage of a low

pressure system and cold front at the ground [5]. Since, overall, the lower parts of the stratosphere are replaced several times per year [22], this implies a particle residence time (e-folding time) of about 50 days. At this rate, 44% of the first day's injected material will be removed in 41 days, and over 95% of it will be gone in 150 days. This provides an absolute minimum rate of the transfer of lower-stratospheric water substance to the surface, as it conservatively assumes completely passive behavior on the part of the injected water substance.

Now let us consider the opposite extreme: water substance is removed from the stratosphere by direct condensation within several days of injection, and so tropospheric/stratospheric exchange mechanisms thereby become unimportant. Under such conditions, the limiting factor becomes the maximum amount of non-ice water substance that the stratosphere can hold for a few to several days. Prior to precipitation, water substance temporarily resides in the stratosphere in the form of vapor. As noted earlier, this corresponds to a conventional water-vapor saturated stratosphere (column loading of to 25 g/cm2[68]). This value pessimistically assumes that water substance has been injected only above the tropopause. (On the other hand, the water substance existing above 30 km, and needing to be subtracted from the loading, is negligible). Moreover, this does not include the possible additional quantity of stratospheric water substance entrained in supercooled droplets, which can exist at temperatures far below freezing (to -40 C [66]), provided that condensation nuclei do not remove them first.

## MICROPHYSICS OF WATER-SUBSTANCE INJECTION

Both homogenous and heterogenous nucleation takes place as moisture-containing air parcels are cooled, and the rates of both processes are accelerated by the cold temperatures [14, 29]. Several factors, discussed below, contribute to the relative unimportance of heterogenous nucleation, and thus reduce the effects of sea-salt and volcanogenic CN's on the crystal-size distribution in the hypercane-generated plume.

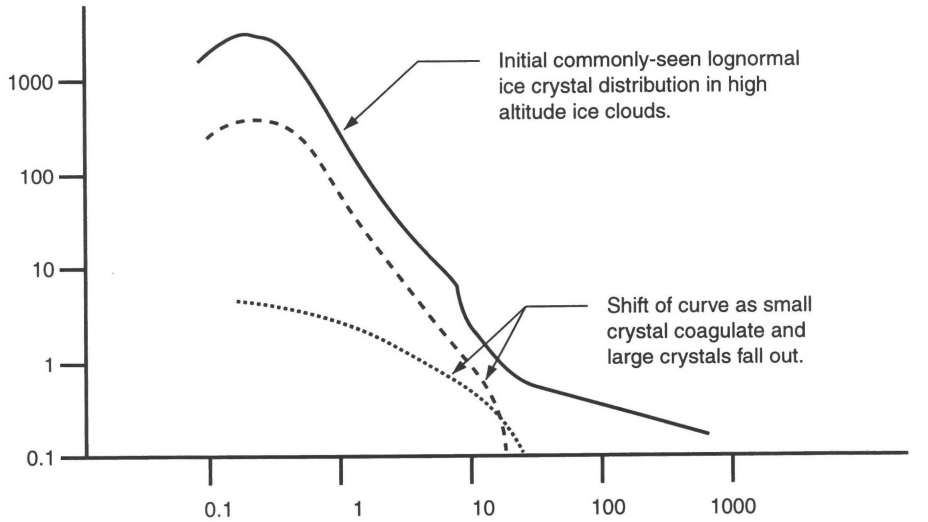
Homogenous nucleation becomes dominant at temperatures below about -40 C [29, 54] and at high updraft velocity [14, 29, 50]. Thus, the differences between seawater and pure water are diminished in terms of their respective potential effects on the eventual size distribution of ice crystals. Likewise, the nucleating effects of any volcanic aerosols present in the stratosphere are minimized [58]. Homogenous nucleation, when contrasted with heterogenous nucleation, favors longer-lasting ice clouds because of a proliferation of many small ice crystals competing for the same water vapor [13, 28]. Also, the high rate of ice-crystal nucleation and growth, at the elevated relative humidity, favors the formation of numerous small ice crystals over a smaller number of larger ones [28]. The nucleation of ice from water vapor is favored over the nucleation of water droplets from vapor at temps 20 degrees below the frost point [66], and the presence of supercooled water below about -40C is rare [66]. Furthermore, as temperatures fall from 0C to stratospheric temperatures (-60C), the saturation vapor density of water vapor over ice becomes increasingly smaller than the saturation vapor density of water vapor over liquid water [42], so water vapor changes directly to ice much more rapidly than it can change to water. At stratospheric temperatures, therefore, almost all of the water material injected by hypercanes is sequestered by tiny ice crystals [69].

Despite the fact that small crystals are favored, we need to at least estimate what fraction of the water substance injected by the hypercanes into the stratosphere precipitated almost immediately in the form of large hydrometeors, and therefore failed to persist long enough in the atmosphere to precipitate over the continents (Fig. 1). Owing to the magnitude of the hypercanes and lack of precise analogues, this is a difficult task. However, several known factors point to the unimportance of large ice particles. The main factor is the rate of updraft of moisture-laden air into very cold air (below about -38C [13]), which, if considerable, will blast-chill the entrained water vapor at such rapid rates that very numerous small ice crystals will form, and very few of these will be large enough to promptly fall out of the ice cloud by sedimentation. (Of course, much water material lofted by hypercanes falls out within the convective cloud of the hypercane itself. Our concern is with that water substance that has already been lifted into the stratosphere). The rapidity of cooling greatly increases nucleation rate [69]. With an extremely rapid cooling in less than 5 minutes at unit supersaturation, ice crystals would theoretically have insufficient time to grow much larger than about 10 microns [69] within the hypercane updrafts.

Hypercane-induced updrafts in the eyewall occur at unprecedented velocities (>60-100 m/sec[20]). Such rates are matched by those of updrafts which follow nuclear explosions. Recently-declassified data [3] on such moisture-laden mushroom clouds indicate ascent rates of 100-200 m/sec for the first 2-3 minutes. The analogy with hypercane-ascending water substance breaks down because the nuclear column is driven

by extreme heat, of which a few thousand degrees may persist for some time after the fireball has ceased to be luminous. This creates a reservoir of thermal inertia in the mushroom cloud which gives time for some of the water to condense and fall out. This thermal inertia is particularly pronounced for megaton-class (million-ton TNT equivalent) explosions [3], owing to the large size of the superheated bubble of air and water vapor. So it is all the more interesting that, despite this fact, some of the Pacific nuclear tests did not create much local fallout even in the case of water-surface bursts. This indicates that, in such instances, nearly all of the injected water substance promptly froze into ice crytals too small to fall out of the stratosphere by sedimentation within a few hours.

Fig. 3 Boundary Conditions (Approximate) Governing the Precipitation of Hydrometeors from Ice Clouds




In the hypercane, of course, conditions for virtually-instant freezing are all the more favorable. Apart from the relatively small amount of heat initially supplied by the ocean-surface thermal anomaly, there never would be any noticeable heating of the ascending material. Thus, unlike nuclear-explosion clouds, there would never be a period of warmth compatible with the condensation of water vapor into large drops. To the contrary: cooling would span the interval of near-surface temperatures (50 C temperature anomaly) to stratospheric ones (-60C) in a short time (<5 minutes), and the rate of this cooling could only be intensified by the adiabatic expansion of moisture-laden air within the eyewall of the hypercane. On this basis, it is possible to seriously contemplate the hypercane updraft of water substance droplets and vapor being so rapid that almost none of the material would freeze into crystals large enough to fall out immediately over the oceans.

Convective storms in the ambient troposphere have updraft rates which range up to about 35 m/sec [27], with some convectively-merged storms off Australia (called "Hectors") possibly attaining updraft velocities of 50-60 m/sec [61] But both are much lower than the 100 m/sec [20] believed true of hypercanes. Even so, the rate of blast-chilling of water substance liquid and vapor to temperatures below -35 C occurs too rapidly for riming processes to take place and form graupel [27]. Thus, while it may conceivably be possible for some hailstones to form as a result of the collision of particles, it is unlikely that much hypercane-injected water substance had been lost in the form of immediate solid precipitation.

**MICROPHYSICS OF ICE CLOUDS**

In contrast to the earlier discussion of the ice clouds which had sublimated into water-vapor anomalies, we now focus on those ice clouds which had largely maintained their integrity up to at least the time they had become advected to locations above continental masses (Fig. 2, Stages III and IV). This section focuses on the changes in ice-particle size distribution within the ice clouds by various endogenous and

exogenous causes. Finally, the dynamics of direct precipitation from these clouds is considered.

Let us consider the microphysical processes which occur in the ice clouds as they are being transported by the ambient stratospheric circulation. Coalescence of ice crystals within the ice clouds themselves is largely ineffective because of the relatively low water substance content [54], and because the time required for crystals in the single-digit micron range to coagulate to a nontrivial extent far exceeds the several days [53, 69] during which the ice clouds containing them are in transit (Fig. 2). The ice crystals follow a lognormal distribution. As shown in Figure 3, the number of ice crystals (per cubic centimeter) vary as a function of diameter in microns, with a modal size of 1 micron or less [42]. Probably very few ice crystals are large enough to fall out of the stratosphere in a matter of minutes. However, many crystals are of sufficient size to fall out over a period of time from several hours to a few days. With gravity-induced settling considered as the only factor, particles of about 10 microns fall 10 kms in 3 days [65], and such approximations have been found to be valid in the light of more sophisticated studies [44] which have taken more variables into account. However, once the particles fall out, they will re-evaporate within about 0.5-1.0 km under the ambient conditions [26] of extreme cold (-60C) and low relative humidity (<20%).

Several researchers [36, 37, 38] have modeled the changes in thick ice clouds resulting from the fallout and re-evaporation of ice crystals. As the hydrometeors evaporate and humidify the atmosphere below the ice clouds, they may, as discussed earlier, simply be sliced and moved away by wind shear, and thus be eventually fated to deliver their entrained moisture into tropospheric synoptic systems. However, if wind shear is not pronounced, the evaporated ice crystals will humidify the atmosphere below the ice cloud to the point of allowing new ice crystals to precipitate. In effect, the ice cloud will "move itself down", over several hours [37]. But since the ice clouds generated by the hypercanes occur at high altitudes, very low temperatures, and assumed very low stratospheric humidities, the rate of this self-induced downward movement will be much slower, allowing the ice clouds to remain in the stratosphere for at least the duration (of a few to several days) that it will take them to be advected over the continents.

If, as described above, ice crystals evaporate and re-condense, heterogenous nuclei can now assume greater significance than had been the case when they had first formed in the hypercane-updraft plume. Large numbers of volcanogenic CCN can contribute to the formation of many smaller crystals, and at lower relative humidities [13, 58], thus tending to counteract the appearance of large numbers of crystals of sufficient size to fall out immediately out of the ice clouds. However, the impact of IN and CCN on stratospheric ice clouds is still not well understood at present [13].

Thus far, we have treated the ice clouds as passive entities. In actuality, they interact with either or both IR and visible solar radiation. At a constant thickness of 2 km, a ice cloud in the stratosphere causes much greater IR forcing than one at lower altitudes [35]. One that is optically thick (typically containing an IWC (ice-water content) on the order of at least 0.1 g/m3 [2]) experiences a large (100 W/m2) forcing at both ranges of wavelengths [35]. The effect of this is a net radiative cooling of the upper portion of the ice cloud and net radiative heating of the lower portion, thus leading to instability and convection [63, 39].

Let us now consider the direct precipitation potentially available from surviving ice clouds (Fig. 2, Stage 4). To do this, we need to first estimate the amount of water substance sequestered in these clouds in the form of microscopic ice crystals. The total number of ice crystals per cubic centimeter is not straightforward to estimate. The concentration of such crystals, in contemporary cirrus anvils resulting from intense convective storms, can be on the order of 100/cm3 [42], with theoretical limits of perhaps 2000/cm3 [24]. The latter compares favorably with extrapolations of ice crystals numbers expected at -60C and at updraft rates scaled to 100m/sec [39]. As a sensitivity analysis, we can consider what concentration of the ice crystals (in #/cm3) would correspond to an IWC of 1.0 g/m3 (derivation given below). This amounts to: 3000 10-micron diameter crystals, 30 20-micron ones, or, theoretically, to a single 120-micron crystal [37], per cubic centimeter of air. These numbers are illustrative, of course, as we would actually obtain a wide range of ice crystal sizes in the cloud, distributed lognormally. Extrapolations from microphysical studies of contemporary ice clouds [25], if valid, suggest that only about 0.1 ice crystals per cubic centimeter, larger than 100 microns, should form at updraft rates near 100 m/sec and at -60C.

Ice crystal loading is a function of updraft velocities, and IWC (ice-water content) of over 1.0 g/m3 have been observed in thunderstorms with convective updrafts exceeding 7 m/sec [30]. This is over an order of magnitude below hypercane updraft rates. By contrast, assuming that LWC (liquid water content), as a

function of updraft velocities, can be legitimately extrapolated to 100 m/sec, a LWC column loading of about 10 g/m3 [27] is implied. Were this LWC all to freeze into submicron ice crystals in the hypercane-generated plume, the LWC would all become IWC, and would mean that a single stationary 10 km ice cloud is sequestering enough water substance to generate 10 cm of precipitable water underneath it.

What about rate of precipitation? Heymsfield [25] has discovered that the precipitation rate of water from ice clouds is a function of IWC, and this function is relatively independent of synoptic conditions over several orders of magnitude:

$$R=3.6IWC(E1.17) \quad (1)$$

where:

R=Precipitation Rate (in mm per hour)

IWC=Ice Water Content (in grams per cubic meter)

On this basis, and assuming that precipitation from ice clouds does not undergo multiple cycles of evaporation and refreezing [33], the quoted water substance loading (10 g/m3) would correspond to a precipitation rate of 53mm/hr. Once rain fell from ice clouds, it would likely be in the form of larger raindrops [66, 43] than occurs from convective clouds at the same rate of rainfall. This would probably heighten the sense of the intensity of the rain among those who experience it.

## CONCLUSIONS AND FURTHER RESEARCH

Assuming that they could have actually formed during the early stages of the Flood at an appreciable frequency, hypercanes would have served as a very effective mechanism for producing the 40-day rainfall. More research is needed to determine if mean winds of less than 1 m/sec are needed to allow hypercanes to develop [20], and at what wind velocities they would be displaced off the oceanic thermal anomalies. We also need to determine how internal dissipation constrains potentially more powerful hypercanes.

This work has not considered the effects of massive amounts of descending stratospheric water substance on synoptic weather systems themselves. This should be investigated, along with any feedback processes.

Precipitation rate scales directly as a function of ocean-surface temperature. Were it eventually found that hypercanes could not exist, we would then need to determine if the thermal anomalies themselves could cause local convection of sufficient intensity to inject water material high enough and for long enough periods of time to cause a dramatic increase of rainfall on distant continents.

Finally, whereas the radiative forcing of individual ice clouds has been considered, the radiative perturbation of the entire stratosphere by massive ice cloud decks has not, to the author's knowledge, been modeled by anyone. Volcanic clouds have been observed to perturb stratospheric circulation on a measurable scale [72], and major changes in atmospheric circulation are modeled to occur as an aftermath of massive smoke injections [24]. The latter are also predicted to cause a decoupling of lower-tropospheric circulation from that of the atmosphere above, as well as that from ocean to atmosphere, as a consequence of severe surface cooling. In the absence of such cooling, any major radiative perturbation of middle atmospheric circulation dynamics by massive ice cloud decks may have the opposite effect--the enhancing of precipitation, thus adding to the amount of water falling on the continents. This global effect could potentially dwarf the actual direct contribution of hypercanes to global precipitation, and clearly merits further study.

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